

# **Resuspension during Storms: Deployment of Gliders as Part of the ONR-OASIS Effort and a Retrospective Analysis**

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## **LONG-TERM GOALS**

Characterizing *in situ* water turbidity is critical to numerous naval operations. In particular, water column turbidity impacts the efficacy of sensors that use optical measurements for a variety of purposes including laser detection of mines and prediction of the operational detection horizon for bioluminescence and diver visibility algorithms. Nepheloid layers, are optically significant and represent a nearly universal turbid feature in the coastal ocean. The maintenance of these nepheloid layers is regulated by the resuspension of material and the relative rates of aggregation and disaggregation. Aggregation and disaggregation rates depend on sediment concentration and turbulence in the water column, which in turn are functions of the wave and current shear stresses at the seabed, the distance from the bottom, and the stratification. Additionally, alternative mechanisms recently observed are associated with storm and tidally induced buoyancy instabilities. Finally, sea floor topography can play a major role in the formation and maintenance of the nepheloid layers. Given these processes, optical and physical data is required in both space and time over a range of sea states. *Our long-term goal is to develop a coherent understanding of the dynamics and optics of nepheloid layers. To accomplish this, particle composition characteristics will be resolved with the relevant physical forcing mechanisms across a wide range of time and space scales.*

## **OBJECTIVES**

We will take part in the interdisciplinary OASIS (2007 **O**ptics, **A**coustics, and **S**tress **I**n **S**itu) program which will collect time series of vertically distributed, co-located observations of shear stress, stratification, dissipation, sediment concentration, sediment size distribution, and multi-spectral optical and acoustical properties in a nearshore bottom boundary layer. These observations will be used to evaluate and improve models of the characteristics of the suspended particles and their effect on optics and acoustics. These efforts are focused around the Martha Vineyard Cabled Observatory (MVCO) during the summer-autumn storm season. We will provide spatial physical and optical time series in support of the bottom mounted OASIS assets using several Slocum Webb Gliders. We will use the Gliders to:

- 1) Provide a 50 by 50 kilometer control volume around MVCO using gliders to constrain the transport of particulate material into and out of the OASIS study site. Combined with the fixed platform high frequency time series data, we will assess the relative importance of local and non-local material transported into MVCO area during resuspension events.

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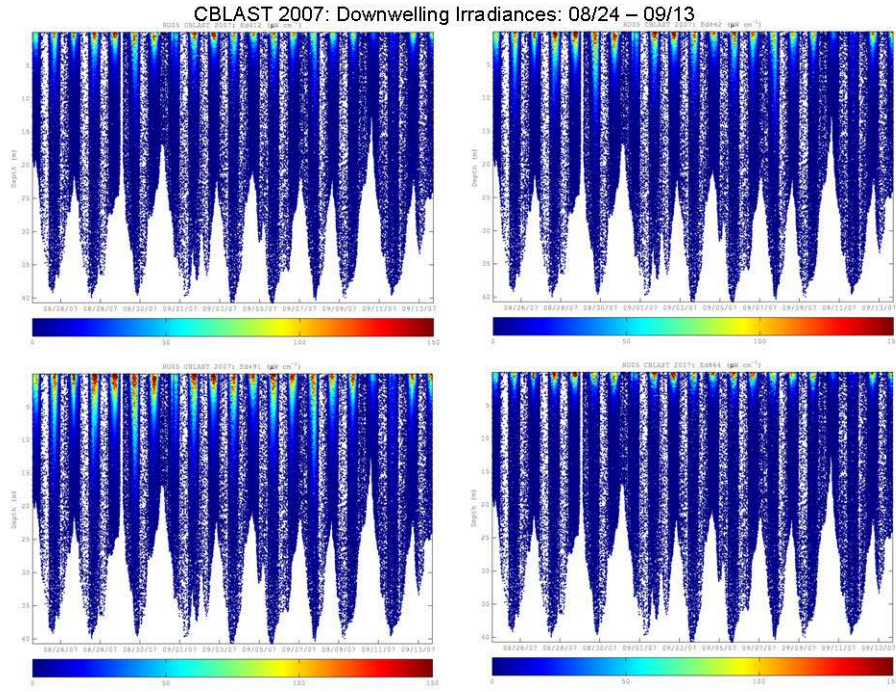
- 2) Characterize the relative importance of buoyancy instability induced and wave induced resuspension. Additionally we will assess how these processes vary spatially.
- 3) Optically characterize the material resuspended into the water column (particle size distribution, organic versus inorganic) and quantify the associated impacts on water clarity.

## **APPROACH**

This effort builds off past deployments of Gliders during OASIS and CBLAST exercises in 2002 and 2005. The gliders have demonstrated the ability to map resuspension events at MVCO. Attenuation data collected by Webb Gliders in 2005 demonstrated that resuspension events varied spatially and temporally. Furthermore the significant presence in non-algal particles during storm induced resuspension was readily evident. In this next OASIS field effort, we propose to several Webb Gliders that are outfitted with spectro-radiometers, backscatter, and attenuation sensors to provide a persistent sustained presence. The gliders will fly a series of cross shore lines around the OASIS array. Field efforts will focus calibrating and refining optically-derived maps of organic and inorganic particle distributions.

## **WORK COMPLETED**

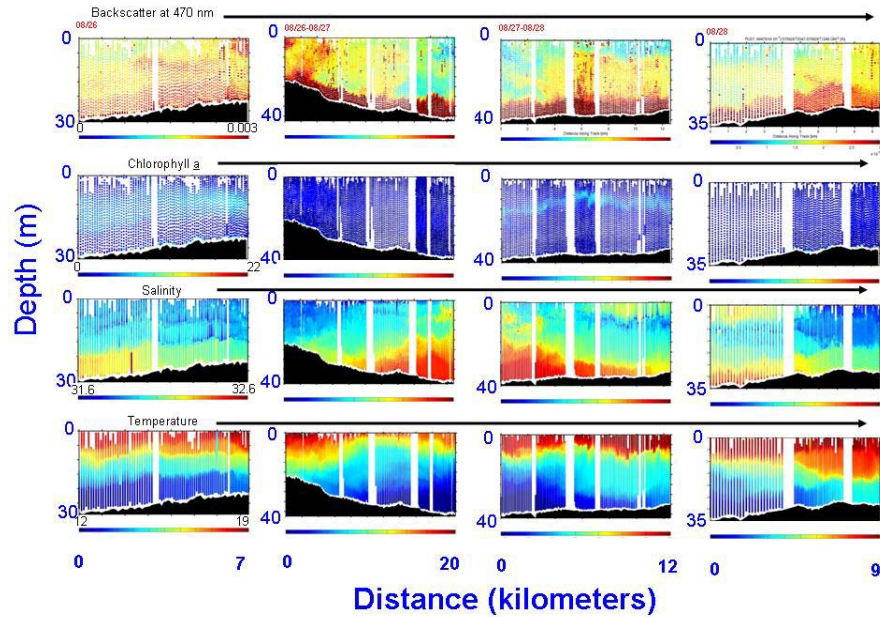
Gliders were deployed from August 15<sup>th</sup> and maintained the 25<sup>th</sup> of September. During the recovery another Glider was deployed as part of a MURI initiative which contributed another week of cross shelf data. The OASIS gliders during this period collected 11,045 vertical casts and traveled 1027 kilometers. The entire data set contained temperature, salinity, currents, spectral backscatter, chlorophyll fluorescence, and CDOM fluorescence. In this deployment we for the first time were able to collect spectral radiometry data from a Glider for close to 70% of the OASIS deployment period. These data streams were processed in near real time and posted to the web. Combined with the MURI transects conducted just prior and after, the OASIS region will be provided with almost 13,000 vertical casts in the immediate area to provide a spatial and temporal context with which to interpret the fixed platform deployments for the OASIS effort. The first radiometry data collected by the glider is presented in Figure 1.



**Figure 1.** Downwelling irradiance measured by a Slocum glider in August and September of 2007. The day to day variability reflects the presence or absence of clouds combined with the material present in the surface waters.

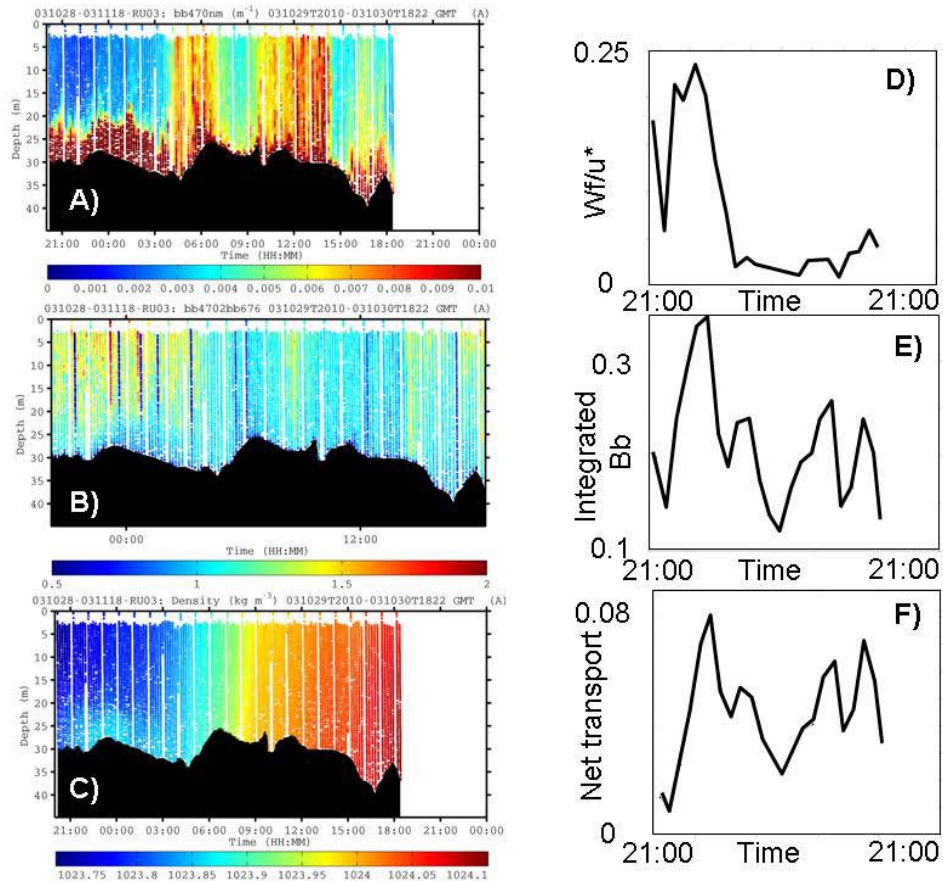
## RESULTS

The data immediately revealed a great deal of the spatial complexity in this area (Figure 2). Also significant variability was observed over short time periods. Optical variability was dominated by nepheloid layers which did not appear to have significant amounts of chlorophyll. The degree with which the nepheloid layer intruded into the surface water was strongly dependent on the presence of any pycnocline being present. To better understand the physical forcing of resuspension we have begun a full retrospective analysis of our larger glider data set.



**Figure 2. Variability in the optical and hydrographic period within a 48 period offshore Martha's Vineyard collected with an optical Slocum Glider during the 2007 OASIS experiment.**

Our analysis has initially focused on some historical storm data collected and for this progress report we emphasize the results surrounding a large tropical storm encountered in October of 2003. This initial event was captured during a transect off the new jersey coast which was a 5 day mission in which it conducted a 120 km line ranging from the 15 m to 100 m isobaths. All gliders are equipped with a CTD, and some include payload bays with optical ECO-sensor pucks. In 2003 the glider encountered a strong storm during the fall transition where the already occurring surface cooling preconditioned the shelf for rapid mixing during a fall storm. The mixing storm of October 2003 was a classic northeaster. Early in the storm when waves were still high, sediment resuspension was limited to below the weakening pycnocline. After the pycnocline was eroded, particles immediately filled the water column (Figure 3). The ratio of backscatter at two wavelengths indicates that the particles are likely similar materials (Figure 3B). This implies the reduced slope of the backscatter profiles is caused by an increase in vertical transport or turbulent mixing. Wave bottom orbital velocities during this time were slowly decreasing, and the glider vertical velocities show no indication of enhanced vertical velocities due to full water column Langmuir cells.



**Figure 3.** *Variability in the optical and hydrographic properties during a storm off the Mid-Atlantic coast. The time dependent changes in backscatter (A), spectrak backscatter ratio (B), density (C),  $Wf/u^*$  (D), water column integrated  $B_b$  (E), and net transport (F) during the nor'easter.*

Results indicate that even a small amount of stratification appears to restrict mixing of sediment across the summer pycnocline. Both tides and surface waves appear to enhance turbulent fluxes that can then mix sediment throughout the water column. The sediment drops out of suspension rapidly after the combined wind, tide and wave forcing is reduced, suggesting its source is a resuspension event. Mean currents estimated from the glider drift also indicate that the changes in the vertical distribution do not appear to be associated with changes in the advection directions. Significant sediment resuspension events observed are not timed with the peak in the wave bottom orbital velocities, that lack of evidence for full water column Langmuir cell activity, yet appear to be correlated with the tides indicates the potential for nonlinear coupling between the three flow components across the surface and bottom boundary layers. Thus variations in the mixed time-space series of optical backscatter data collected by the glider appear to be more related to the tidal variations in time than the topographic variations in space.

## IMPACT/APPLICATIONS

The Navy's mission has transitioned from a deep blue water tactical theatre to a littoral environment; however present Naval operational capabilities do not have the required data fidelity to deal with the complexity of coastal waters. These shortcomings are compounded as traditional sampling approaches

are quickly compromised in denied access regions. The development of a long duration covert capability for collecting environmental (hydrographic and optical) data will offer a new paradigm in solving this problem. Using mine counter measures as an example, optical data would feed back on submersed and aircraft laser line scan mission planning by impacting the effective depth at which the laser can “see”. If the environmental characterization is performed over relevant scales the applications will assist real world missions, including mine detection and mine-counter measures, Special Forces operations, amphibious landings, shallow water anti-submarine warfare and force protection from terrorism

## **RELATED PROJECTS**

The Mid-Atlantic Bight rapid environmental assessment Multidisciplinary University Research Initiative (MURI) will provide follow-on opportunities to develop and test advanced data assimilation techniques for coupled optically based physical-biological models using physical datasets similar to those acquired during OASIS. Data assimilation experiments from ONR’s SW06 indicated that glider sampling scheme that focused on resolving processes in the mooring array produced an excellent hindcast of the stratification in the immediate vicinity of the moorings, the desired result for the SW06 process studies. However, the limited spatial extent of the data relative to the forecastable mesoscale resulted in poor forecasts of the shelf wide flows. This prompted the MURI glider sampling strategy to begin testing the shelf wide glider flights that are now zigzagging along the shelf sweeping across the larger area with the mean flow from Cape Cod, MA to Cape May, NJ. The effect of this larger scale sampling on forecast skill is now being evaluated. The OASIS sensors will now provide the data feed for the project.

Lessons learned from OASIS experiment on the Mid-Atlantic’s outer shelf are now being applied to glider sampling and forecasting activities associated with the Rapid Environmental Assessment MURI, and the recently funded Mid-Atlantic Bight Regional Coastal Ocean Observing System (MARCOOS). Both of these Navy and NOAA projects will in turn provide a larger scale context for the locally intensive NSF Ocean Observing Initiative Pioneer Array to be deployed on the Mid-Atlantic Bight outer shelf. The enhanced activity on the Mid-Atlantic shelf provides a potential testbed for the Navy’s Littoral Battle Space Fusion and Integration (LBSF&I) initiative, a program that is expected to purchase a large number of gliders for sustained environmental assessment in forward deployed areas with similar oceanographic conditions.

## **PUBLICATIONS**

- Glenn, S. M., Jones, C., Twardowski, M., Bowers, L., Kerfoot, J., Webb, D., Schofield, O. Riders in the storm: Studying resuspension processes in the Mid-Atlantic Bight with Slocum Gliders. *Limnology and Oceanography* (submitted)
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